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TEN EUROPEAN COUNTRIES BUILD THE LAUNCHER "ARIANE"

P. Langereux

Translation of "Dix pays européens construisent le lanceur 'Ariane'," Air et Cosmos, No. 521, March 16, 1974, pp. 29-35

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16. Abstract

Scheduled for completion in 1980, the Ariane launcher will be the first European rocket launched using a cryogenic stage powered by liquid hydrogen and oxygen. The main technical specifications for the launcher's three stages are given, with a description of its flight characteristics. Economic information on its manufacture includes a list of the contractors involved and their assigned tasks. The Ariane will enter series production in the 1980's to meet a projected European demand for 35 to 50 geostationary satellites during that decade.

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TEN EUROPEAN COUNTRIES BUILD THE LAUNCHER "ARIANE"

Pierre Langereux

Six months after the decision by the ministers of the European Space Conference to undertake a new European heavy launcher project to replace the "Europa 3," construction of the launcher "Ariane" (formerly "L.III.S") is actually underway. /29*

Technical specifications have been obtained, the principal contractors have been chosen, the industry is organized and financial backing is increasing.

Today, however, manufacturers already possess the necessary technical documents, tools and production machines, as well as the initial components of the future launcher: structural components (rings, shrouds, etc.), tank models, turbopumps, engines and even propellant assemblies for the first stage.

Research is even already well advanced in preparation of the "Viking" engines, which have been under development for several years by the LRBA [Laboratoire de recherches balistiques et aerodynamiques; Ballistics and Aerodynamics Research Laboratory] and subsequently by the SEP [Société Européene de Propulsion; European Propulsion Company]. There have already been more than 1500 bench tests of the turbopump, and the complete engines, "Viking 1" and "Viking 2," have already been operated at the test bench more than 1000 times within rated conditions.

Between "Thor Delta" and "Atlas Centaur"

The objective of this project, researched by the CNES [Centre national d'études spatiales; National Space Research Center],

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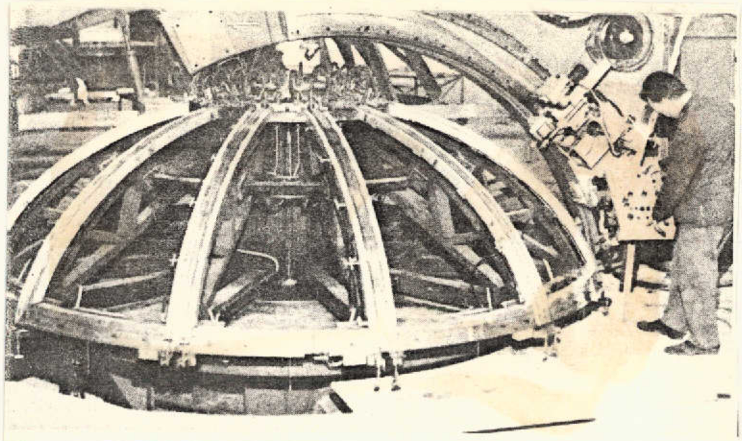
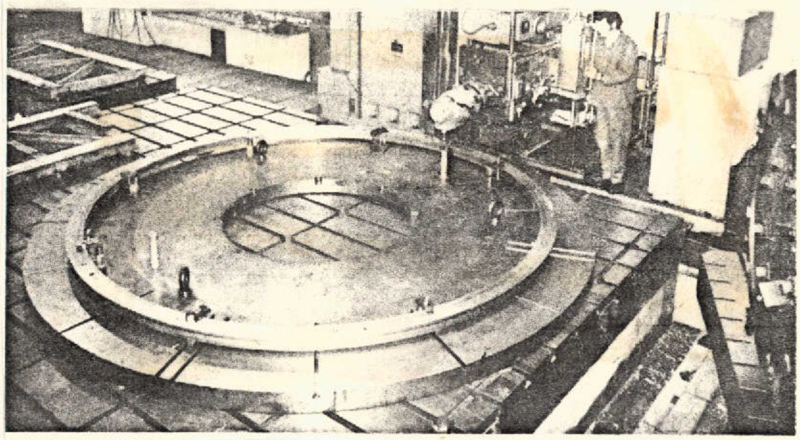
* Numbers in the margin indicate pagination in the foreign text.





The Aerospace Administration has just installed a machine at Mureaux to weld the tank floors of the first stage L 140, which alone represents an investment of 100 million francs (upper). Other machines, used for several years in the ballistics program or the national program, will be used to build the "Ariane." The lower photograph shows a ring being machined for the L 140 tank at Mureaux.

the DTEN [expansion unknown] and the industry on request from Mr. Debré of the National Defense Ministry and Mr. Charbonnel of the Ministry of Industrial and Scientific Development, is to provide by 1980 a launcher for 750 kg geostationary satellites which is economically competitive with equivalent American launchers.

In actual fact, with its height of 47.4 m and its takeoff weight of 201 t (unloaded), the Ariane will be situated between the

McDonnell Douglas Thor Delta (100 t takeoff weight), which places 2 t in low orbit and 700 kg in geostationary orbit, and the General Dynamics Atlas Centaur (150 t), which, under the same conditions, launches 6 and 2 t respectively.

The European launcher should be able to place in a 200/36,000 km transfer orbit a useful load of 1500 kg, that is a satellite weighing approximately 750 kg with its apogee engine. It will also be able to place 2.5 t in an Earth orbit at an altitude of 1000 km, and subsequently, through reinforcement of the equipment compartment by which the structure supports the satellite, a 4.5 t load. By way of comparison, it should be recalled that the Europa 2 was able to place only 1.2 t in a low orbit and 200 kg in geostationary orbit. As for the Diamant B.P. 4, designed for much lighter missions, this launcher is designed to place 150 kg in a circular orbit at an altitude of 500 km.

First European Rocket with a Cryogenic Stage

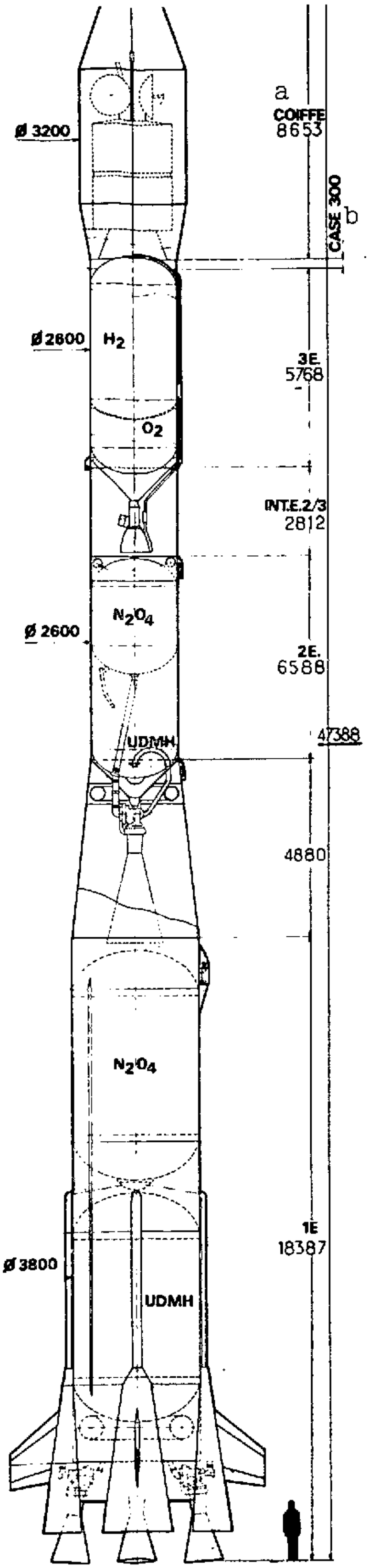
The Ariane is basically constructed of aluminum alloys (A-Z5G and A-U4G1), with the principal exception of the first stage tanks, which are built of the same steel (15 CDV6-Vascojet 90) as the first stage of the Diamant.

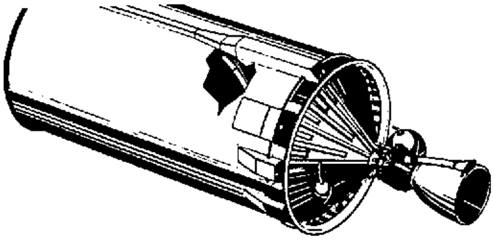
This is a three-stage launcher, whose first stage (L 140) measures 3.8 m in diameter and alone has a takeoff weight of more than 153 t, with its 140 t of hypergolic ergols, nitrogen peroxide (N_2O_4) and asymmetric dimethylhydrazine (UDMH), the same fuels as those used in the Diamant and the second stage of the Europa 2 manufactured in France. The ergols for the L 140 are stored in two separate identical tanks which are pressurized by the hot gases from the gas generator activating the single-shaft turbopump of the engines. The stage is propelled by four Viking 2 engines with 60.8 t thrust per unit on the ground, that is, 243 t takeoff thrust.

The second stage (L 33), with a diameter of only 2.6 m, weighs more than 36 t with 33 t ergol (UDMH and N_2O_4), stored in two tanks divided by a common floor and pressurized by helium stored under high pressure. The stage is propelled by a single Viking 4 engine with 71 t thrust in a vacuum; this engine is directly derived from the Viking 2, primarily by adapting the delivery tube (0.5 m prolongation) and placing the engine on two axes (±5°) rather than only one. Under these circumstances it would be possible to increase the weight of the useful load by 100 kg by replacing the conical delivery tube of the L 33 with an "egg-cup" delivery tube which would improve the specific impulse by 10 sec. This could only be accomplished by additional expenditures and developmental research, however, since no /31
European firms have built such tube so far.

The third stage (H 8) also measures 2.6 m in diameter, but it carries 8.2 t liquid hydrogen and oxygen stored in tanks with an intermediate common floor, heat-insulated by resin and a vacuum cavity. The stage itself is protected by an external coating of Klegecell. The tanks are pressurized by gaseous hydrogen furnished by the engines and by helium under pressure, for the liquid hydrogen and oxygen tanks, respectively. French scientists have already had some experience in the technology of these cryogenic ergols permitting high specific impulses (430 sec), in the form of research conducted by the SEPR [Société d'étude pour la propulsion par reaction; Research Association for Propulsion by Reaction] and subsequently by the SEP since 1962. The same is true of the HM7 engine with 5.9 t of thrust which propels this stage and which is fed by a turbopump driven by a two-stage turbine (380 kW) rotating at 62,000 rpm. However, this will be the first time that a liquid hydrogen and oxygen-powered stage built in Europe will undergo space travel. Moreover, this is the critical point of the program. Development has been facilitated, however, by choice of a nonreignitable, low-pressure engine (30 bars). Experience with

« ARIANE »





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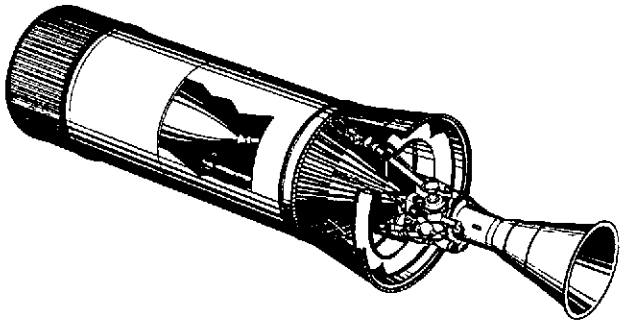
3 ETAGE H 8



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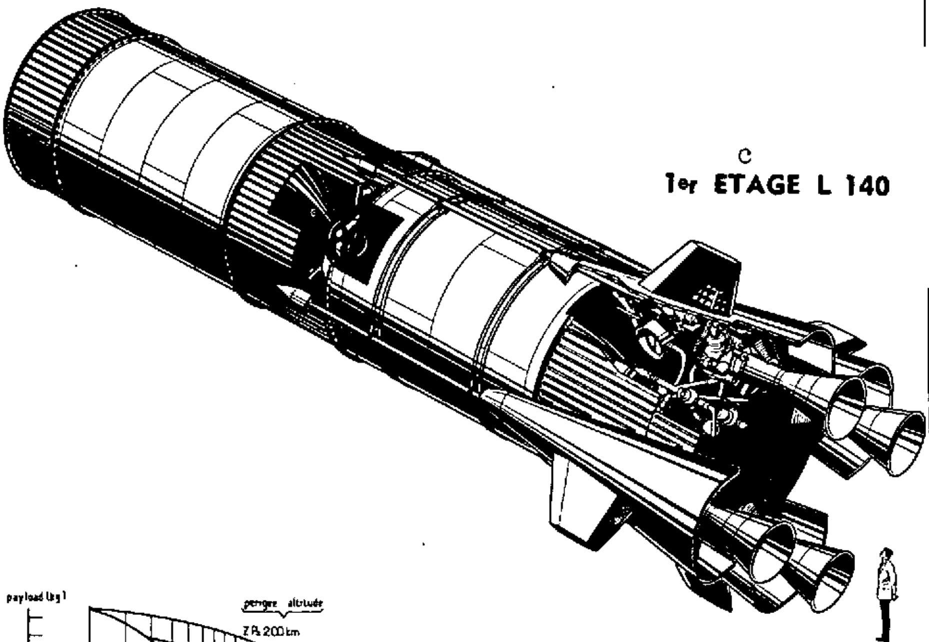
2 ETAGE L 33



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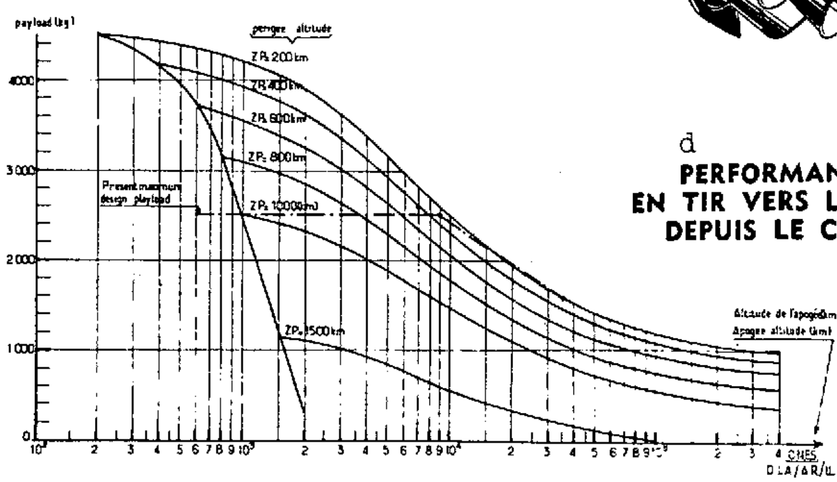

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PERFORMANCES EN TIR VERS L'EST DEPUIS LE C.S.G.

[Caption and key on following page]

Caption and key to figure, p. 5

Final configuration diagram of the launcher Ariane (left) and three stages L 140, L 33 and H 8. All the engines are turbopump-propelled, single-tube, and nonreignitable. The chart at the bottom of the figures shows the performance of the launcher, fired to the east.

Key:
a. Nose cone
b. Chamber
c. Stage (typ.)
d. Performance when fired to the east from the CSG [Centre Spatiale Guyanais; Guiana Space Center]

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the American "Centaur" has shown that this technique imposes severe restrictions on design and leads to a much more complex developmental process. The stage should be in positive acceleration throughout the entire ballistics flight phase so as to assure that the pumps will be properly fed for reigniting. The most important requirement, however, is the provision of reinforced and jettisonable insulation and an in-flight purge system for the tanks to prevent any detrimental heating of the ergols -- and these complications do not even include the restarting equipment. Nevertheless this formula has interested the ESRO [European Space Research Organization], which recommends that it be studied for subsequent versions. Furthermore, given the availability of an equatorial launching site which permits direct firing, the reignitable engine will not be necessary in the immediate future.

The "head" of the launcher is, of course, the equipment chamber, located above the third stage, which coordinates all navigation and guidance functions and operative sequences. It also includes the telemeasurement, remote control, trajectography and command destruct equipment.

The bubble nose cone, consisting of two jettisonable half-shells is constructed of metal with windows composed of stratified glass-resin, permeable to radio waves. With a total volume of

TECHNICAL SHEET FOR THE LAUNCHER "ARIANE" (L 140 + L 33 + H 8)

First stage, L 140

Total weight of structures	13.270 t
Total takeoff weight of stage	153.270 t
Total takeoff weight of ergols	140.000 t
Height	18.387 m
Diameter	3.800 m
Total takeoff thrust	243 t
Total thrust vacuum	277 t
In-flight combustion time	138 sec

Interstage Skirt 1°-2°

Total weight	0.600 t
Height	3.848 m
Diameters	3.8/2.6 m

Second stage L 33

Total weight of structures	3.243 t
Total takeoff weight of stage	36.271 t
Total takeoff weight of ergols	33.028 t
Height	7.620 m
Diameter	2.600 m
Total thrust in vacuum	71.3 t
In-flight combustion time	129 sec

Interstage skirt 2°-3°

Total weight	0.340 t
Height	2.800 m
Diameter	2.600 m

Third stage H 8

Total weight of structures	1.131 t
Total takeoff weight of stage	9.369 t
Total takeoff weight of ergols	8.238 t
Height	5.780 m
Diameter	2.600 m

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TECHNICAL SHEET FOR THE LAUNCHER "ARIANE" (L 140 + L 33 + H 8)
[continued]

Third stage H 8 (continued)	
Total thrust in vacuum	5.9 t
In-flight combustion time	563 sec
Equipment Compartment	
Total weight	0.273 t
Height	0.300 m
Diameter	2.600 m
Cap	
Total weight	0.810 t
Height	8.653 m
Diameter	3.200 m
Useful volume	35 m^3
Total height of launcher	47.388 m
Total empty weight of launcher	19.667 t
Total takeoff weight without payload	200.933 t

35 m^3, it possesses a cylindrical part 4 m high and with an internal diameter of 3 m, providing adequate space to carry a satellite the size of the American Intelsat 4.

Direct Injection

The Ariane will be placed in orbit by direct injection, at an altitude of 200 km, without an intermediate ballistic phase. The probability of failure is equal to the possibility of one failure in 10 firings.

In the case of injection into a geostationary orbit, for example, the launcher will first follow an ascending trajectory

CHARACTERISTICS AND PERFORMANCE OF THE "ARIANE" ENGINES

	Viking 2	Viking 4	HM. 7
Ergols	UDMH-N_2O_4	UDMH-N_2O_4	LH_2 - LO_2
Total ground thrust	60.8 t	—	—
Total vacuum thrust	69.3 t	71.3 t	5.9 t
Ground specific impulse	239 s	—	—
Vacuum specific impulse	278 s	285 s	[illegible] s
Ground combustion pressure	54 bars	—	—
Vacuum combustion pressure	53 bars	53 bars	[illegible] bars
In-flight operation time	138 s	131 s	563 s
Fuel mix ratio (oxidant-fuel)	1,87	1.87	4.5
Total ergol flow rate on ground	255 kg/s	—	—
Total ergol flow rate in vacuum	250 kg/s	250 kg/s	[illegible]4 kg/s
Gas generator flow rate	6.7 kg/s	6,7 kg/s	[illegible] kg/s
Turbine rotation speed	9 500 rpm	9.600 rpm	62.[illegible] rpm
Cross section ratio	13.88	21,15	[illegible]
Diameter of pipe outlet	1.140 m	1,407 m	[illegible] m
Engine height	2.870 m	3,380 m	[illegible] m
Engine weight	695 kg	750 kg	[illegible] kg

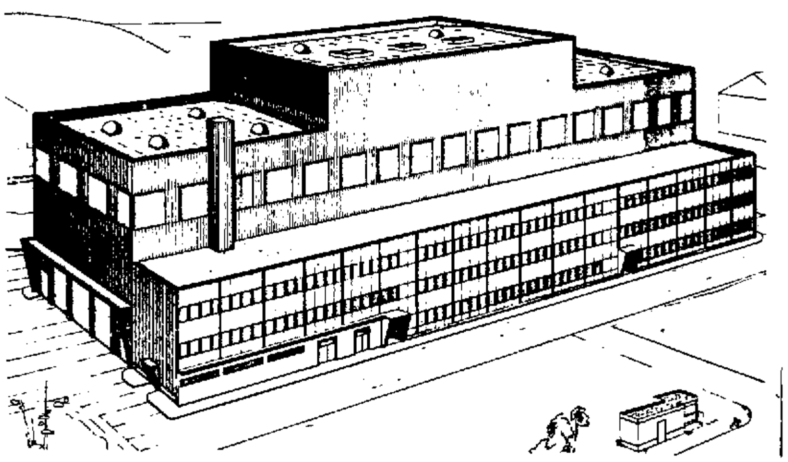
for 20 sec before it is maneuvered into the azimuth imposed by the safety conditions of the launching site and water-side population zones. The first stage will fire for 138 sec, bringing the launcher to an altitude of 483 km and speed of 1800 m/sec. Five seconds later, after the first stage has separated, the second stage engines will ignite while the launcher again tilts so as to place the perigee of the transfer orbit over the equator. The nose cone is jettisoned 244 sec after takeoff at an altitude of 210 km, and 28 sec later, the on-board computer commands suspension of the engine thrust and separation of the stage. The altitude at this point is 129 km and the speed is 4660 m/sec. Then, 281 sec after takeoff, the third stage engine ignites and fires /32 for 563 sec to place the payload at an altitude of 200 km with a speed of 9760 m/sec, after 844 sec of flight, more than 4000 km east of the coast of Guiana. Following a phase of attitude and orientation control, the payload will be separated and injected into a 200/36,000 transfer orbit, which will be brought into circular configuration at the geostationary altitude by the satellite apogee engine.

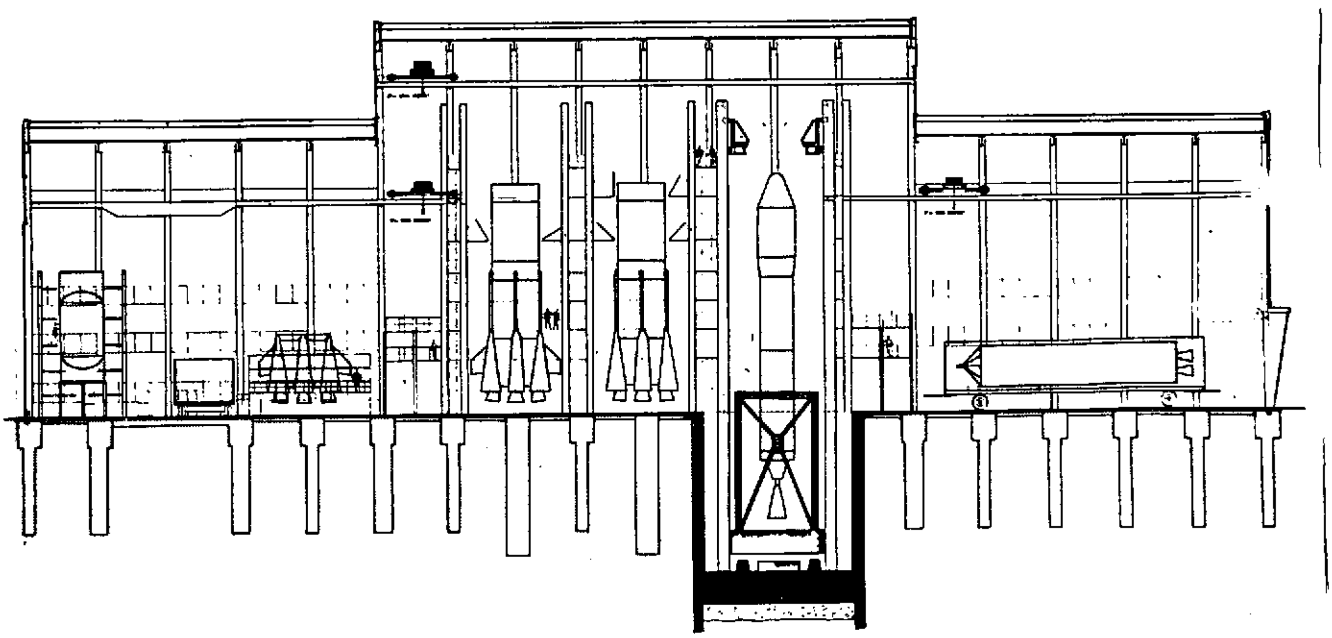
The Ariane rockets will be launched from the Guiana Space Center of the CNES in Kourou (French Guiana). More precisely, they will be launched from the former launching site for the Europa 2 rockets, a large part of which will be reused: launch stand, blockhouse, access ramps, service tower, umbilical tower, assembly hall, ergol storage installation, nitrogen manufacturing plant, office. These installations will obviously be modified and complemented for the Ariane project. Thus new means of transport to Kourou are being provided for the stages arriving by sea (L 140) and by air (L 33 and H 8), as well as a new assembly hangar for the large Ariane satellite, which will be financed by France. It will also be necessary to reinforece the tracking and measuring equipment of the CSG due to the flight time of the Ariane. Thus, in addition to the two Bretagne radar units and the two Adour radar units at Kourou, it will be necessary to obtain data from the radar units at the Natal launching site in Brazil and those of NASA on Ascension Island. Similarly, the Fortaleza station (Brazil) will be dismantled and its telemeasurement devices distributed to two other better located stations along the Brazilian coast.

Developmental Period of 7 1/2 Years

The development and qualification of the launcher "Ariane" should extend for 7 1/2 years, from mid-1973 to 1980. The developmental plan is actually a compromise between rapid implementation of the program to meet the required deadlines and extensive planning to avoid peak operational periods which would subsequently result in heavy layoffs.

The first three years will be devoted to qualification of the stage components (engines, structures, equipment) and to the beginning of tests on the propellant assemblies (January 1976) and on dynamic models (February 1976) and electrical models (July 1976) of the launcher.





Artist's rendering of the future SIL building under construction at Mureaux for assembly of the Ariane. Here the launchers will be controlled in two parts, the first stage, and the combined second and third stages, since the height of the rocket will preclude its being erected completely as on the launching site. With 4000 m^2 of floor space, the SIL will be divided into four work areas with a central hall 33 m high, equipped with an overhead travelling crane.

Also, during this period, the most expensive new testing means will be installed, such as the launcher integration site (SIL), which will go into operation in October 1975, and the Vernon (Eure) test benches, which will require an investment on the order of 200 million francs. The principal test benches installed specifically for the Ariane will include the large PF 20 bench for tests on the complete L 140 stage with its four engines, as well as three cryogenic benches: PF 41, for tests on the turbopump and the HM7 engine; PF 42, for tests on stages with heavy tanks ("battleships"); and PF 43, for tests on flight stages. It may seem surprising that all this test equipment will not be available at Vernon until the beginning of 1976. Until then, however, cryogenic tests will be conducted at the SEP center at Villaroche, which subsequently will function at least until the beginning of 1977. In Germany, the DFVLR benches at Lampoldhausen will be modified for tests on the second stage /33 engine, especially in simulated altitude conditions, as well as the test bench for the propulsion chamber of the HM7 at the MBB Company at Ottobrunn.

The second developmental period will last approximately 1 1/2 years and will include the development and qualification of all stages (from November 1977), as well as adaptation of the Guiana launching site (July 1977).

Finally, a 2 1/2 year period will complete the program with in-flight tests of four Ariane launchers consisting of two developmental flights -- March 25, 1979 (!) and the beginning of November 1979 -- and two qualifying flights, at the beginning of May and the beginning of November 1980.

Series Production for Two Flights Per Year

As soon as the first Ariane launcher is accepted (in May 1978), the ministers of the ten participating countries should meet once again to conclude a new agreement authorizing the series production of the launcher, whose manufacturing cycle is approximately 2 years, since the agreements made so far deal only with the development of the launcher. However, it appears that this time the launcher has been intended for series production from the beginning -- which was not the case with the Europa 2.

According to research performed in 1972 in France, Germany and Great Britain and recently brought up to date, the potential market for the Ariane launcher will be from 35 to 50 civil geostationary satellites weighing 400 to 700 or 800 kg during the next decade, both for European needs (telecommunication satellites under development by ESRO and wire broadcasting satellites projects), European participation in worldwide systems (meto, control of air and maritime traffic) and the needs of third world countries (telecommunications, educational television).

However, it appears that the actual market will be less ambitious than these figures indicate, since launching installations are dimensioned only for two launches per year, that is, approximately 20 satellites between 1980 and 1990.

As for the cost of launching the Ariane, this is currently estimated at 63 million francs (cost basis January 1973), once again at a rate of two launches per year and assuming a rational grouping of control systems.

A 3500 Million Franc Program

The ten member nations of the ESRO, which will participate in the program on a fixed cost basis and not on a pro-rated GNP basis, are nevertheless assured of an 80% return on their /34
contributions in the form of industrial contracts. They have agreed to finance the cost of development of the launcher (2600 million francs), a 20% margin for possible technical risks

GEOGRAPHIC AND INDUSTRIAL DISTRIBUTION OF PRINCIPAL TASKS AND SUBCONTRACTS

Country (participation)	Firms	Tasks
France (62.5%)	Aérospatiale (1)	Industrial architect, integration tests of the three stages, L 140 structures.
	S.E.P. (1)	Responsible for propellant assemblies for the three stages.
	Air Liquide (1)	Structures for H 8 cryogenic stage
	MATRA (1)	Responsible for equipment compartment and test benches.
	ONERA	Systems analysis and technical assistance.
	Intertechnique	PCM telemeasurement (with SAT).
Germany (20.12%)	M.A.N.	Water tanks and L 140 engine mount; gas generators and Viking turbopumps.
	Dornier	Main tanks for L 33.
	ERNO	Engine mount, skirts, water tank and assembly for L 33.
	MBB	HM7 combustion chamber and main valves; telemeasurement antennae and test bench equipment.
	DFVLR	Tests and measurement systems for L 33.
Belgium (5.00%)	SABCA	L 140 stabilizers and fairings, servo motors for all three stages.
	F.N. - Herstal	L 140 and L 33 main valves and control units; L 140 pressurization.
	ETCA-ACEC	L 140 and H 8 test benches and launcher test benches, control centers and housings for command destruct.
	Bell Telephone Mfg.	Window for launcher test benches.

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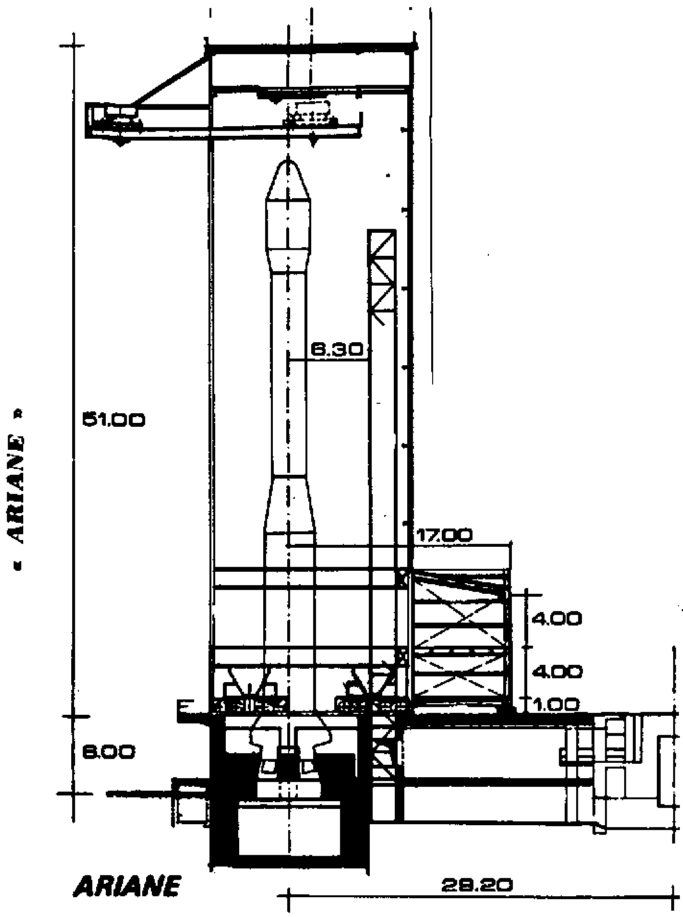
GEOGRAPHICAL AND INDUSTRIAL DISTRIBUTION OF PRINCIPAL TASKS AND SUBCONTRACTS
[Continued]

Country (participation)	Firms	Tasks
United Kingdom (2.47%)	Ferranti Hawker-Siddeley G.E.C.-Marconi Avica	Inertia guidance compartment and its control window. Steering unit, H 8 pressurization and electric valves, launch platform brackets. Guidance analysis, on-board software. Compensating pumps for HM 7 ergol conduits.
Netherlands (2.00%)	Fokker-V.F.W. N.L.R. Philips T.I.	H 8 engine mount, interstage skirts. Aerodynamic tests. Magnetic recorders for test benches
Spain (2.00%)	CASA Standard Electrica SENER	L 140 forward and intertank skirts, electronic equipment. Electronic equipment. Launch table, umbilical tower and related equipment.
Italy (1.74%)	Aeritalia Snia Viscosa Laben	Technological control, technical assistance. Powder-driven propulsion units for stage separation. PCM telemeasurement test bench
Switzerland (1.20%)	Contraves	Nose cone.
Sweden (1.10%)	S.A.A.B. Volvo	On-board analog computer. Viking 2 injectors.
Denmark (0.50%)	Christian Rovsing TERMA	Cylinder electronics, on-the-ground software equipment, computer equipment. Test bench windows.

(1) These firms are the main contractors, responsible for all subcontracted tasks.
(2) France is currently responsible for the remaining unassigned 1.37%.



In order to reuse the "Europa" tower and launch stand for the "Ariane," it was necessary to embed the launcher and the launch table in the platform by 6 m and also to increase the height of the towers by 6 m.

(412) million francs, the internal expenses of the ESRO (14 million francs) and maintenance costs for the former Europa 2 launch stand (39 million francs), that is a total of 2525 million francs (cost basis January 1973). This is on the theory that the launcher will qualify for acceptance with two consecutive successful flights.

France has additionally taken responsibility for a supplementary 15% margin for technical risks (309 million francs), the expenses (100 million francs) of the CNES crew, which is technically and financially responsible for the program for which Aérospatiale is the industrial architect, and the operational expenses of the Guiana Space Center, which a budget report has estimated at 600 million francs through 1980.

The overall cost of providing the Ariane launcher thus comes to more than 3500 million francs (the equivalent of the Europa 2 expenditure), with more than 2600 million francs so far carried by France alone.

ESTIMATED COSTS OF DEVELOPMENT OF THE "ARIANE"

Integration of complete launcher (industrial architect)	110 million francs
L 140 (structure: 100 million francs; propulsion: 345 million francs; assembly: 105 million francs)	550 million francs
L 33 (structure: 100 million francs; propulsion: 100 million francs; assembly: 60 million francs)	260 million francs
H 8 (structure: 60 million francs; propulsion: 271 million francs; assembly: 39 million francs)	370 million francs
Equipment chamber (four chambers)	50 million francs
Research and testing of electrical circuits	20 million francs
Nose cone (two models)	35 million francs
Test benches	62 million francs
Skirts between stages 1 and 2 and 2 and 3	34 million francs
Ground testing (electrical models: 16 million francs; dynamic models: 17 million francs; functional models: 22 million francs)	65 million francs
In-flight testing (four flights: 262 million francs; SIL: 10 million francs; replacements: 17 million francs)	279 million francs
Launching site in Guiana (adapted from Europa 2 project)	140 million francs
UDMH plant (extension of existing plant)	12 million francs
Technologic controls (two equipped models)	15 million francs
Technical assistance and specialized research (technical improvement of launcher and performance, cost reduction)	68 million francs
Cost of development aside from contingencies	2060 million francs
Margin for technical contingencies (20%)	412 million francs
Cost of development with contingencies	2472 million francs

Note: This cost is expressed in francs at their current value on January 1, 1973. It is based on normal development of the launcher permitting acceptance after two successful flights

[Note continued on following page]

Note. (continued)

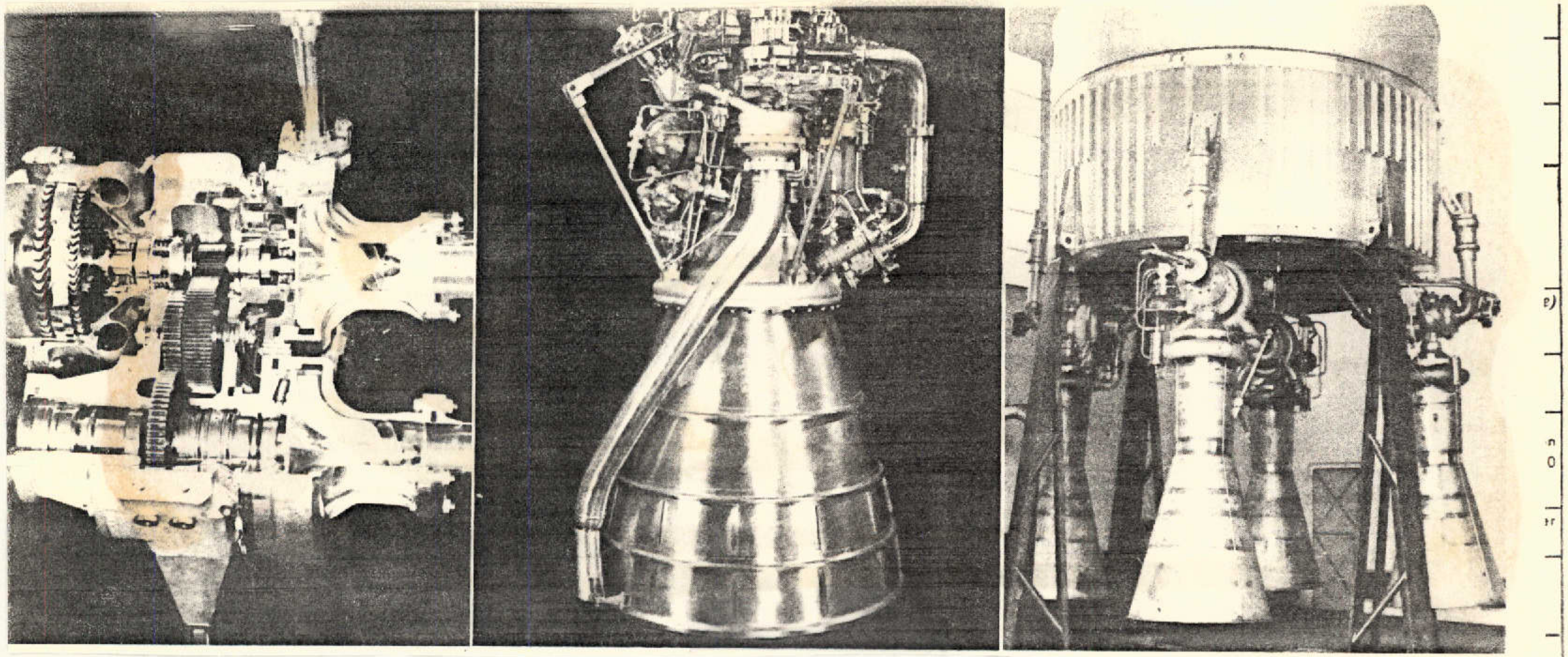
(out of the four flights projected). The relative expenses for the three stages represent 1586 million francs and include delivery of 19 prototypes and 45 Viking 2 series engines with 10 complete tests, 11 Viking 4 engines with four complete tests, and 16 HM 7 cryogenic engines.

Valorization of National Industry

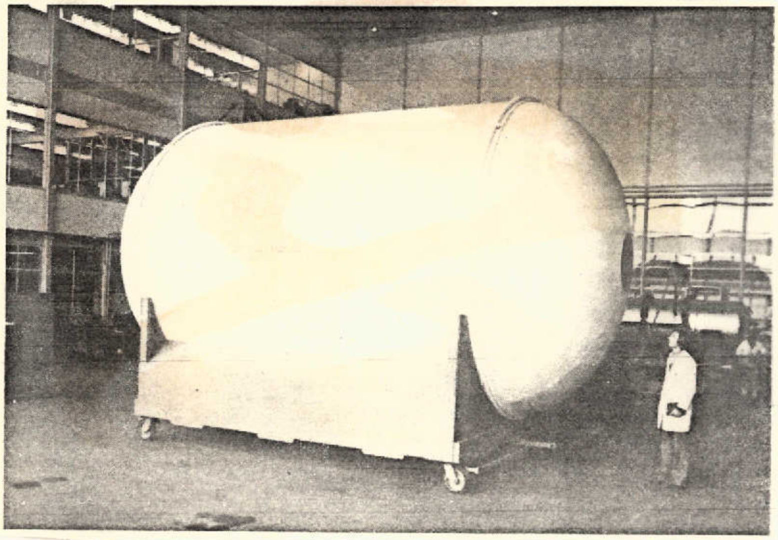
In addition, the Ariane program will have relatively heavy repercussions on the production schedule of French industrial firms, which without this program would definitely have to break up experienced technical teams. This represents a turnover of 660 million francs (of which 290 million francs are subcontracted to foreign firms) for Aérospatiale (300 employees), 716 million francs (300 million francs subcontracted) for SEP (500 employees), 60 million francs (10 million francs subcontracted) for Air Liquide (60 employees), and 115 million francs (75 million francs subcontracted) for MATRA (50 employees). Overall, more than 1000 individuals in French industry will participate in this program before 1980, and subsequently approximately 500 for regular production. /35

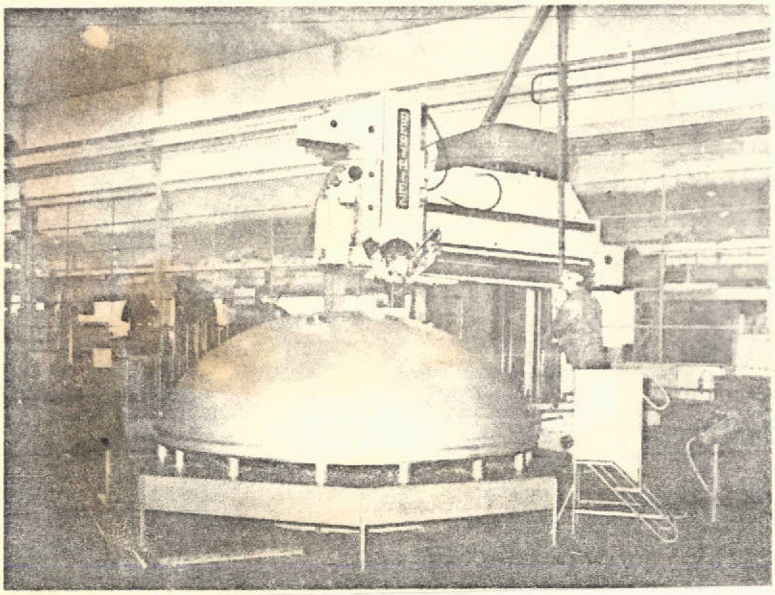
Purposely comprising a "conservative" program with few technological innovations in order to reduce costs and risks, the Ariane project nevertheless makes use of the experience acquired in 10 years of space research and furthers the ambitions of Europe in this area.

But it will also have a more long-term impact on the quality and competitiveness of national industry, both from a European and a worldwide standpoint. The success of this project requires, among other qualities, the use of management procedures for large-scale, precise, efficient projects which have so far been lacking in Europe.



Models of turbopump (left) and HM 7 liquid hydrogen and oxygen engine (center) which will propel the third stage of the Ariane launcher and the propellant assembly for the L 140 first stage (right) with its four Viking 2 engines producing a total takeoff thrust of approximately 240 t. The European Propulsion Company, which is responsible for the development of the propellant assemblies for the three stages of the launcher, is supplying the engine, ergol, pressurization, and command assemblies, and the propellant structures and servo motors, and is responsible for performing and exploiting integrated tests. In addition, the SEP will assemble the propellant assemblies for the first and third stages.





Model of one of the two tanks for the L 140 first stage of the Ariane (below). Machining a hemisperical cap for the floor of the L 140 tank on a Berthiez vertical tower at Mureaux.

The "Z Launcher"

Finally, the CNES also wishes to profit from the Ariane program by deriving from it a lightweight national launcher consisting of a two-stage upper part (L 33 and H 8) to which will be added a third stage P 008 (Diamant). According to the CNES, it will be possible to complete this project in 3 1/2 years (1977 to 1980), and thus in the same time period as that required for the Ariane project, with only two test flights, but allowing for additional expenses. This successor to the Diamant B P4, christened the "Z Launcher," will be able to place a 575 kg satellite in a circular equatorial orbit at an altitude of 400 km, permitting a slight increase in size for French satellites.